The characterisation, treatment and sustainable reuse of biosolids in Ireland

J. Bartlett* and E. Killilea**

* Department of Environmental Science, Institute of Technology, Sligo, Ballinode, Sligo, Republic of Ireland
** Department of Civil Engineering, Institute of Technology, Sligo, Ballinode, Sligo, Republic of Ireland

Abstract Ireland is an island country on the western boundary of the European Union. A suite of environmental legislation over the last decade has combined to increase the amount of municipal sludge for treatment fourfold, while, simultaneously, eliminating traditional disposal methods. The Irish Government has instituted a comprehensive programme of policy development, infrastructure provision and drafting of "codes of good practice" to meet these environmental and legislative challenges. As the programme has developed, it has become clear that the sludge/biosolids issue shares many of the philosophical and logistical elements of other environmental issues that are developing apace in Ireland, including municipal waste management, agricultural waste management and overall integrated development. In many ways, it represents a model of the ultimate "sustainable development" issue. To provide specific data for decision making and policy/infrastructure/technology development, the Irish Government has funded a US$600k programme of research in The Characterisation, Treatment and Sustainable Reuse of Biosolids. The design philosophy of the programme is a "cradle-to-grave" approach, in order to integrate the outcomes of specialised research studies into an overall sustainable development model.

Keywords Biosolids; characterisation; reuse; sludge; sustainable development; treatment

Introduction Ireland is an island country on the western boundary of the European Union (EU). It has a highly developed economy and is recognised as a centre for high-tech manufacturing (O’Connell et al., 1999). However, this profile is a relatively recent phenomenon. Until the late 1980s, Ireland had a largely agrarian economy and a relatively underdeveloped environmental services/management infrastructure. In the last decade, major investment programmes, supported by the EU, have delivered a comprehensive environmental management infrastructure (DoELG, 1999). Planned investment is set to continue the pace of this provision (Fitzgerald et al., 1999).

In parallel with environmental infrastructure development in the 1990s, rapid economic development has brought a significant increase in overall industrial output, increased urbanisation and other development factors that have added to pressures on the environment (EPA, 2000). Increasing European Union environmental controls have further amplified resource requirements. In many cases, local authorities in Ireland are finding that the need for environmental management infrastructure is keeping pace with, or outgrowing, the rate of supply. This is leading to significant problems, particularly in the area of waste management (DoELG, 1998).

The topic of sludge generation and sustainable management is one of the waste management issues that has come to the fore in Ireland within the last decade. It is a topic that can be viewed as a model of the wider “sustainable development” issue. In common with the challenge of sustainable development, sludge management has features of an increasing production/demand profile in the face of a dwindling range of management options, both in the context of increasing public awareness of the hazards of poor management and of individual responsibilities for contributing to solutions.
The following paper sets out the development of the sludge/biosolids management issue in Ireland to date and describes a comprehensive research programme, designed to provide data for use in the framing of a sustainable reuse solution.

**An increase in the amount of sludge for treatment and in the required standard for reuse in agriculture**

Ireland’s environmental infrastructure in the 1980s was characterised by the existence of few secondary wastewater treatment facilities, particularly in towns and villages with population equivalents (PE) below 10,000. As an island country, Ireland had two further features that defined its municipal wastewater sludge generation profile. The first was that more than 50% of the population lived in towns or cities on the coast, virtually none of which had secondary wastewater treatment and, secondly, almost all sludge generated in coastal towns and cities was disposed of directly to sea (Weston-FTA, 1993).

**Increased standard of treatment**

Where sludges were generated, prior to 1991, the practice of recycling of sewage sludge, without further treatment, was widespread and successful in Ireland. In 1991, Statutory Instrument (S.I.) 183 of 1991 introduced European Council Directive 86/278/EEC (*on the protection of the environment, and in particular the soil, when sewage sludge is used in agriculture*) into Irish law. The intent of this Directive was twofold, firstly to promote recycling of sludge in agriculture and, secondly, to set a consistent standard in order to protect the environment and guarantee quality. S.I. 183 (of 1991) prohibited the use of untreated sewage sludge in agriculture and set out minimum treatment standards for sludge intended for use in agriculture. Treated sludge, meeting appropriate standards, is defined in mandatory guidance documents as “biosolids”.

However, because there were few capital facilities available to treat the sludge to the specified standard, and no short-term prospect of the introduction of appropriate facilities, the response of most local authorities was to divert sewage sludge from beneficial reuse, primarily to landfill (Bartlett, 2000).

**Increased amount for treatment**

In 1994, S.I. 419 of 1994 introduced European Council Directive 91/271/EEC (*concerning urban waste water treatment*) into Irish law. This Directive required the provision of secondary wastewater treatment facilities for towns with populations in excess of 200, on a phased basis, before 2015. In 1996, the Dumping at Sea Act (no. 14 of 1996), giving effect to the OSPAR convention of 1992, eliminated the dumping of municipal sludges at sea from 1999. These two legislative instruments combined to increase the predicted amount of sludge for treatment from 37,500 tonnes dry solids (tds) in 1993 to 129,795 tds in 2013 (Weston-FTA, 1993). Most recent estimates, used in current individual local authority sludge management plans indicate that the predicted amounts may increase by, on average, 20% by the year 2020 (FTC, 2001). This, in total represents a fourfold increase in municipal sludge for treatment between 1993 and 2020.

**Reduced options for disposal**

The Waste Management Act of 1996 (no. 10 of 1996) and European Council Directive 1999/31/EC (*on the landfill of waste*) have combined to effectively preclude the disposal of untreated municipal sewage sludge to landfill, on the basis of its liquid and organic contents.

Treated sludge, or biosolids, is also effectively precluded from disposal, except in the...
case of material used specifically as a product for daily or other landfill cover (i.e. beneficial reuse).

Figure 1 illustrates the impact of legislative and infrastructure developments on the quantities of municipal sludge for treatment in Ireland and on available options for disposal. Quantities are expressed in percentages, relative to a baseline of 84,000 tds (i.e. including sea disposal amount) in 1993 (expressed as 100%).

The 1993 column shows that over 50% of sludge generated in that year was disposed of at sea. Approximately 40% of the total was reused in agriculture, with approximately 10% disposed of to landfill. The major change in 1994 was that the agricultural reuse option was severely restricted (except for some plants, where the required treatment standard was achieved, primarily through the “six months storage” treatment option). In 1994, up to 90% of all sludge generated was disposed of, either to sea, or to landfill.

The major change in 2000 was that the sea disposal route had been eliminated. In that year, the total amount generated had increased by over 20%, with all of it now requiring further treatment to meet the agricultural use standard (hence the fourfold increase in total for treatment). As sufficient treatment capacity was still not available, all sludges not meeting the standard (i.e. 90% of all sludge generated) was sent to landfill.

The major change in 2005 (*predicted profile) is that the landfill route will be, effectively, eliminated. The challenge, therefore, is to establish a comprehensive treatment network to produce a standard of treated sludge (biosolids) suitable for use in agriculture and to make the beneficial reuse options acceptable to end-users (farmers and consumers).

The development of Irish government policy on sludge management and beneficial reuse of biosolids

In the last decade, a number of studies have been carried out in order to support policy development on the municipal sludge issue. The first was the 1993 Strategy Study on Options for the Treatment and Disposal of Sewage Sludge in Ireland. This study identified all existing sources of municipal sludge, predicted new sources, predicted changes in amounts generated and proposed the delineation of sludge treatment regions, with “hub-towns” where treatment would be centralised. Options for treatment were identified and recommended for each region, in the light of costs and logistics and subject to further detailed sludge management planning in each area (Weston-FTA, 1993).

A 1997 study of international practices in the use of biosolids in agriculture followed. That study detailed European, American and other global patterns of sludge generation and reuse/disposal. Specific reference was made to sludge characterisation and potential contaminants in product biosolids (Bartlett, 1998). The findings of the study were used in the subsequent setting of standards in guidance documents.

Next, a set of guidelines for producers and end-users of biosolids was drafted. The
guidelines were divided into major sludge management plans for local authorities and “codes of good practice” for biosolids use (directed at both producers and end-users).

Each local authority in Ireland is required, under the Waste Management Act, 1996, to prepare waste management plans for their functional areas. Non-hazardous sludges (i.e. municipal wastewater sludges, but also including municipal water sludges, agricultural and some industrial sludges) were the subject of a specific guidance document that set out the manner in which the sludge management plans should be framed and implemented. Specific sub-sections of that guidance document dealt with “evaluating the potential for agricultural use of biosolids” and “treatment processes to achieve biosolids for land-based management strategies” (FTC, 1998a).

In order to expedite the application of the sludge management plan, the guide was further developed in a “model sludge management plan”, within which the exercise was carried out for a selected local authority (FTC, 1998b).

The most recent stage in the development of a policy framework was the drafting of a (mandatory) “Code of Good Practice for the use of Biosolids in Agriculture”. This was prepared in two parts, one for the local authority producer, the other for the farmer, as end-user (FTC, 1999a,b). These documents set out the Irish Government’s commitment to the beneficial reuse of biosolids, identified potential constraints to reuse, established procedures for reuse systems and set quality control standards for sludges, biosolids and agricultural land receiving biosolids. By and large, the target standard is equivalent to the USEPA “Class A” standard, or a pasteurised product.

The development of sludge management infrastructure

The Irish National Development Plan 1994–1999 recognised the country’s responsibilities under the Urban Wastewater Directive and put in place an investment programme to meet the infrastructure requirements. In all, 24 schemes were commissioned (the majority completed) to meet the 2000 deadline, at a cost of US$875m. The current National Development Plan (2000–2006) has continued this investment. A further 62 schemes are to be built to meet the 2005 deadline, at an additional cost of US$500 m (DoELG, 2000).

There are a small number of sludge treatment plants operating at present, including thermophilic aerobic digestion in Killarney, anaerobic digestion in Tralee, Tullamore, Clonmel and Roscrea, and thermal drying in Dublin and Clonmel. Furthermore, all local authorities have initiated their sludge management planning process and are actively considering options for treatment and reuse options. It is expected that the majority of these will be operational by 2005 (FTC, 2001).

In the original strategy study, a range of treatment technologies were investigated and recommended. These included anaerobic digestion, aerobic digestion, alkaline stabilisa-

Table 1 Irish sludge management policy and guidance documents

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<th>Stakeholder group</th>
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<td>National Government</td>
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<td>1997 Study of international practices on the use of biosolids in agriculture.</td>
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<td>1998 Inventory of non-hazardous sludges in Ireland.</td>
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<td>Local Government</td>
<td>1998 Guide to the preparation and implementation of sludge management plans.</td>
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<td>1999 Code of good practice for the use of biosolids in agriculture.</td>
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<td>Farmers</td>
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tion, thermal drying, and composting. Economies of scale were noted to be of importance, particularly with capital intensive options, such as thermal drying (Weston-FTA, 1993). It is interesting to note that, in the intervening period, a combination of reducing capital costs and particular product characteristics perceived to be desirable for marketing (i.e. a dry product) have tended to favour thermal drying as a treatment technology (DoELG, 2001).

The role of research
There are many technical issues associated with the selection of the optimum sludge treatment/biosolids reuse system. It is a complex waste/resource management issue and one that suffers from a considerable lack of fundamental data (Bartlett, 1995, 1998; Matthews, 1996; RCEP, 1996). It is an interdisciplinary issue that requires a number of areas of expertise in the drafting of a long-term, viable solution. However, no research study to date has examined an integrated and sustainable approach to the characterisation, treatment and disposal/reuse of sludge/biosolids.

A three-year sludge/biosolids research programme was proposed by Institute of Technology, Sligo (IT, Sligo) for funding in 2000. There are seven specific post-graduate projects within the programme, each is an individual research study, providing valuable knowledge in its own right. Taken together, the range of projects will provide a “cradle-to-grave” assessment of the life cycle of sludges. Results from each individual project will inform the others and will also form part of the long-term research effort on the topic.

The projects can be grouped broadly into five categories: (1) full-spectrum characterisation, necessary because many of the concerns about the reuse of biosolids in agriculture are based on fear of unknown constituents, (2) an assessment of the effects of historic dumping at sea, (3) specific parameters of concern (i.e. oestrogenic compounds and uranium), (4) sludge treatment technologies and (5) sustainable reuse (i.e. land application and the establishment of sustainable development indicators (SDI)).

The research programme involves the Institute of Technology, Sligo, as the “lead” institution and seven partner institutions from the institute of technology, university, government and private sectors. The total value is over US$600k. The Higher Education Authority (HEA) granted funding in 2000, under the Irish Government’s Programme for Research in Third Level Institutions (PRTLI).

Finding a sustainable reuse solution
Sustainable development in practice will require all stakeholders in a particular environmental situation to make decisions and to act responsibly in the light of the best available information and with the best interests of future generations in mind. In many ways, the sludge issue encapsulates the wider “sustainable development” issue. Firstly, the material is both a waste that must be treated and a resource that should be beneficially reused. Secondly, there are a number of stakeholders, representing every section of society, who each have a responsibility for generating the material and for establishing an effective management system.

In addition, from a legislative point of view, biosolids forms an important element in our responsibilities for recycling, waste management and resource management. However, there are some concerns about biosolids reuse, primarily related to potential contamination of foodstuffs.

Biosolids is a pasteurised product, considered to be suitable for reuse in agriculture as a fertiliser and soil conditioner. At a macro-level, beneficial reuse of biosolids in agriculture could be viewed as closing the nutrient cycling loop. Nutrients taken from soil in food crops in rural areas are, ultimately, converted to biosolids in urban wastewater treatment plants and returned to rural soils. At a micro-level, however, it is difficult to demonstrate this connection to consumers who fear a potential health risk.
Beneficial reuse of biosolids must be viewed in the context of Ireland as an agricultural country. The entire amount of municipal sludge for reuse represents less than 1% of the total amount of agricultural sludges recycled each year in Ireland (4.35 m tds in 1998) (FTC, 1998c). There is no significant imperative (other than a currently altruistic “sustainable development” responsibility) either for farmers to take biosolids, or consumers to buy food from land fertilised with it. In the absence of a mandatory reuse strategy, which is most unlikely, either group can, at the moment, simply choose not to become involved. This could effectively eliminate beneficial reuse of biosolids.

How then to achieve the objective? A fundamental element must be the generation of comprehensive data on the nature of sludges/biosolids and on the implications of beneficial reuse. Another must be the education of stakeholders so that decisions can be made in the context of the best available information. Beneficial reuse programmes must be designed with a clear underlying philosophy of sustainable development, in order to engage stakeholders’ understanding of their long-term responsibilities. Most importantly, each stakeholder must be assured that the practice does not involve unacceptable risk.

If a system can be designed that effectively meets each element of the overall objective, it may well serve as a model for other sustainable development issues.

Conclusion

The beneficial reuse of biosolids in agriculture presents many challenges, including effective education of stakeholders of the full scope of the issues involved and the design of a sustainable system. Fundamental to meeting the biosolids challenge is a requirement for comprehensive data from research into sludge characterisation, sludge treatment systems and sustainable development indicators. The integrated sludge research programme described is designed to address this complex issue.

References

DoELG (2001). Personal communication.